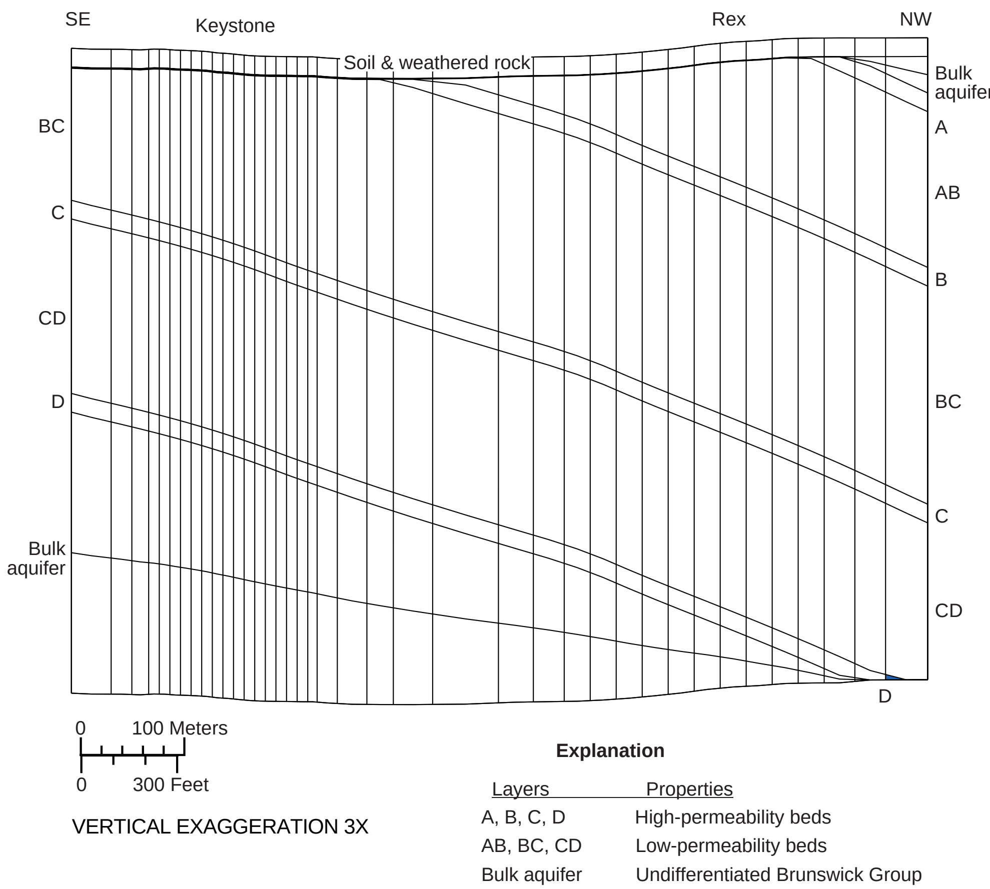
SIMULATION OF AQUIFER TESTS AND GROUND-WATER FLOWPATHS AT THE LOCAL SCALE IN FRACTURED SHALES AND SANDSTONES OF THE BRUNSWICK GROUP AND LOCKATONG FORMATION, LANSDALE, MONTGOMERY COUNTY, PENNSYLVANIA

U.S. GEOLOGICAL SURVEY
Open-File Report 00-97



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Cover: Cross-section of a three-dimensional ground-water flow model showing dipping high- and low-permeability beds of the Brunswick Group in northwestern Lansdale, Pennsylvania (see figure 24 of this report, and related discussion). “Keystone” and “Rex” designate properties where aquifer tests were conducted to provide drawdown and recovery data for calibration of the model.

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Lemoyne, Pennsylvania
2000

U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

Charles G. Groat, Director

For additional information write to:

District Chief
U.S. Geological Survey
840 Market Street
Lemoyne, Pennsylvania 17043-1586
Email: dc_pa@usgs.gov

Copies of this report may be purchased from:

U.S. Geological Survey
Branch of Information Services
Box 25286
Denver, Colorado 80225-0286
Telephone: 1-888-ASK-USGS

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ILLUSTRATIONS

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TABLES

CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
inch (in)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
	Area	
square foot (ft^2)	0.09290	square meter
square mile (mi^2)	2.590	square kilometer
	Volume	
gallon (gal)	3.785	liter
gallon (gal)	0.003785	cubic meter
	Flow rate	
foot per day (ft / d)	0.3048	meter per day
gallon per minute (gal / min)	0.06309	liter per second
	Hydraulic conductivity	
foot per day (ft / d)	0.3048	meter per day
	Transmissivity	
foot squared per day (ft^2 / d)	0.09290	meter squared per day

Vertical datum: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

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ABSTRACT

The U.S. Geological Survey, as part of technical assistance to the U.S. Environmental Protection Agency, has constructed and calibrated models of local-scale ground-water flow in and near Lansdale, Pa., where numerous sources of industrial contamination have been consolidated into the North Penn Area 6 Superfund Site. The local-scale models incorporate hydrogeologic structure of northwest-dipping beds with uniform hydraulic properties identified in previous studies. Computations associated with mapping the dipping-bed structure into the three-dimensional model grid are handled by a preprocessor using a programmed geographic information system (GIS). Hydraulic properties are identified by calibration of the models using measured water levels during pumping and recovery from aquifer tests at three sites. Reduced flow across low-permeability beds is explicitly simulated. The dipping high-permeability beds are extensive in the strike direction but are of limited extent in the dip direction. This model structure yields ground-water-flow patterns characteristic of anisotropic aquifers; preferred flow is in the strike direction. The transmissivities of high-permeability beds in the local-scale models range from 142 to 1,900 ft^2/d (feet squared per day) (13 to 177 m^2/d). The hydraulic conductivities of low-permeability parts of the aquifer range from 9.6×10^{-4} to 0.26 ft / d (feet per day) (2.9×10^{-4} to 0.079 m / d). Storage coefficients and specific storage are very low, indicating the confined nature of the aquifer system. The calibrated models are used to simulate contributing areas of wells under alternative, hypothetical ground-water-management practices. Predictive contributing areas indicate the general characteristics of ground-water flow towards wells in the Lansdale area. Recharge to wells in Lansdale generally comes from infiltration near the well and over an area that extends upgradient from the well. The contributing areas for two wells pumping at 10 gal / min (gallons per minute) extend about 1,500 ft (feet) upgradient from the wells. The contributing area is more complex at ground-water divides and can extend in more than one direction to capture recharge from more than 3,300 ft away, for pumping at a rate of 30 gal / min. Locally, all recharge in the area of the pumping well is not captured; recharge in the downgradient direction about 150 ft from the pumping well will flow to other discharge locations.

INTRODUCTION

Ground water in the area of the Borough of Lansdale, Pa., has been withdrawn since the early 20th century for use as drinking water and for industrial supply. In 1979, water from public-supply wells in the area was found to be contaminated with trichloroethylene (TCE), tetrachloroethylene (PCE), and other human-made organic compounds (CH2M Hill, 1991). Through additional sampling, an area of ground-water contamination was identified, and the site, known as North Penn Area 6, was placed on the National Priority List (NPL) by the U.S. Environmental Protection Agency (USEPA). The North Penn Area 6 site encompasses about 3 mi^2 (square miles) [2.6 km^2 (square kilometers)] and includes at least six sources of contamination on separately-owned properties largely within the Borough of Lansdale (CH2M Hill, 1991). The site is located on the U.S. Geological Survey (USGS) Lansdale and Telford 7.5-minute topographic quadrangle maps (fig. 1).

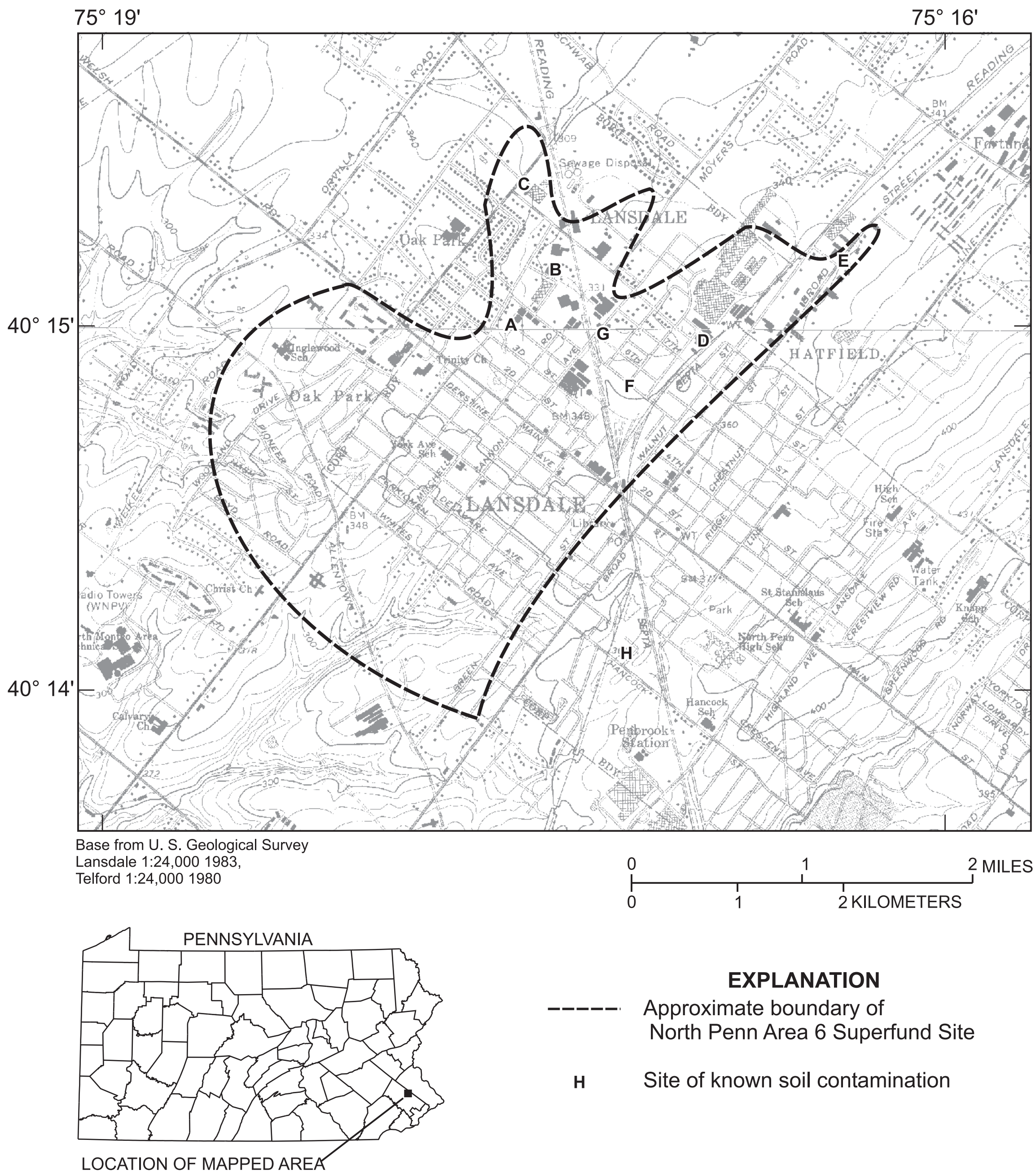

Figure 1.-- Location of North Penn Area 6 site, Lansdale, Pa.

Since 1995, abandonment of public-supply wells in favor of an alternative surface-water supply source and closure of industrial facilities has changed the location and rate of ground-water withdrawals in Lansdale. Concerned about contaminant migration, the USEPA needed information about the effects of these changes in water use on the direction of ground-water flow. In 1995, the USGS, in cooperation with USEPA, began a study to describe the ground-water system and simulate ground-water flow on a regional scale using a numerical model in the area of Lansdale. Data collected for the study from 1996 through 1998 included geophysical logs of wells, water levels in wells, streamflow measurements, aquifer-interval-isolation tests, and multiple-well aquifer tests (Conger, 1999; Senior and Goode, 1999). This work was done to assist the USEPA in preparing a remedial investigation and feasibility study (RI/FS) of the North Penn Area 6 site (Black & Veatch Waste Science, Inc., 1994, 1998).

The numerical model used by USGS (Senior and Goode, 1999) to simulate ground-water flow in the area of Lansdale provided estimates of bulk aquifer transmissivity and general ground-water-flow paths on a regional scale, but not at the local or site scale. The regional-scale model structure did not incorporate local heterogeneity or the geologic structure of dipping beds, aquifer characteristics that appear to affect local ground-water flow as determined from aquifer tests at four properties in North Penn Area 6 in 1997 (Senior and Goode, 1999). Therefore, the USGS proposed, in late 1999, additional simulations to more accurately simulate ground-water flow at the local scale in selected areas where pumping may be used as part of the ground-water remediation.

Purpose and Scope

This report presents numerical simulations of ground-water flow using the porous-media model MODFLOW (Harbaugh and McDonald, 1996) at the local scale for two areas in and near Lansdale, Pa. The simulations are based on a model structure that includes the geologic structure of dipping beds.The automatic, nonlinear optimization program, MODFLOWP (Hill, 1992), is used to calibrate the model to water levels measured during aquifer tests done in 1997. Contributing areas for wells pumped during these aquifer tests and drawdown in the pumped well and observation wells are simulated.

Previous Work

Work done by USGS for USEPA on North Penn Area 6, Lansdale, Pa., is described in reports by Goode and Senior (1998), Conger (1999), and Senior and Goode (1999). Senior and Goode (1999) discuss results of numerous previous studies in the Lansdale area. Aquifer tests at the J.W. Rex Co. property are summarized in the report prepared by QST, Inc. (1998).

Acknowledgments

The additional work done for simulation of ground-water flow at the local scale was initiated from reviews of the regional scale model by Gregory Ham and Kathy Davies of the USEPA and Lusheng Yan of Black & Veatch Waste Science, Inc. Data for aquifer tests at the J.W. Rex Co. property were provided by Brian Loughnane of ESE, Inc.

SUMMARY AND CONCLUSIONS

Ground water in the Lansdale area is contaminated with organic solvents, and contaminant migration is of concern as pumping patterns in the area change. The U.S. Geological Survey (USGS) provided technical assistance from 1995 to 1999 to the U.S. Environmental Protection Agency (USEPA) in remedial investigations at the North Penn Area 6 site, Lansdale, Pa. This assistance included describing the ground-water system and simulating of ground-water flow on a regional scale. Lansdale is underlain by dipping beds of Triassic-age shales, siltstones, and sandstones of the Brunswick Group and Lockatong Formation that form a layered aquifer. The calibrated regional model indicated that the aquifer appeared to be anisotropic; transmissivity is greatest in the strike direction of underlying rocks. However, the regional model did not incorporate local hydrogeologic detail that could be inferred from geophysical logs, aquifer tests, and other data. In late 1999, the USGS began additional modeling of ground-water flow in selected areas of Lansdale on a local scale.

On a local scale, ground-water flow in the Lansdale area occurs primarily in high-permeability bed-oriented features that dip northwest with the regional geologic structure. Numerical models of local-scale ground-water flow are developed using the dipping hydrogeologic structure and measured water levels during aquifer tests at three locations in north-central and northwestern Lansdale. Predictive contributing areas for individual pumping wells are simulated using the calibrated local-scale flow models, in conjunction with a previously developed calibrated steady-state model of regional flow.

The local-scale flow models approximately simulate measured drawdown and recovery during pumping. The heterogeneous hydrogeologic structure is explicitly incorporated in the local-scale models, and the hydraulic properties of the dipping beds are identified by model calibration. The complex three-dimensional structure in the models cannot be included in simpler analytical models commonly used for aquifer-test analysis. Transmissivities determined from calibration of the local-scale models, nevertheless, are similar to those calculated using analytical methods for the aquifer tests. Computations associated with mapping the dipping bed structure into the three-dimensional model grid are handled by a preprocessor using a programmed geographic information system. Reduced flow across low-permeability beds is explicitly simulated. The dipping high-permeability beds are extensive in the strike direction but are of limited extent in the dip direction. This model structure yields ground-water-flow patterns characteristic of anisotropic aquifers; preferred flow is in the strike direction. The transmissivities of high-permeability zones in the local-scale models range from 142 to 1,900 ft^2/d (13 to 177 m^2/d). The hydraulic conductivities of low-permeability parts of the aquifer range from 9.6×10^{-4} to 0.26 ft/d (2.9×10^{-4} to 0.079 m/d). In comparison, the geometric mean or “effective” transmissivity of the regional scale model was 1,050 ft^2/d, a value that lies in the range of transmissivities determined from the local-scale model and represents bulk properties of the Brunswick Group aquifer. Storage coefficients and specific-storage values are very low, indicating the confined nature of the aquifer system.

Predictive contributing areas indicate the general characteristics of ground-water flow towards wells in the Lansdale area. Recharge to wells in Lansdale generally comes from infiltration near the well and over an area that extends upgradient from the well. Locally, all recharge in the area of the pumping well is not captured; recharge in the downgradient direction about 150 ft from the pumping well will flow to other discharge locations. The contributing areas for two wells pumping at 10 gal/min (Mg-1609 in north-central and Mg-1610 in northwestern Lansdale) extend about 1,500 ft upgradient from the wells. The contributing area is more complex at ground-water divides and can extend in more than one direction and capture recharge from more than 3,300 ft away, for pumping at a rate of 30 gal/min (well Mg-625 in northwestern Lansdale). The contributing area for well Mg-625 in northwestern Lansdale is compared for simulations using the local-scale model and the previously developed regional scale-model. The contributing area simulated by the regional-scale model is more elongated in the strike direction than the contributing area simulated by the local-scale model. Differences in the shape of the contributing area simulated by the two models may be caused partly by grid-size differences and the anisotropic character of the aquifers in the regional-scale model.

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